CO_2 GREENHOUSE UPDATE 1985

- Lamont-Doherty Research

- CRSL Research
  + Contribution to DOE State of the Art Report
  + Oceanic effects on transient climate change

- Budget Status, Proposal

- DOE and other reports

- Recent research developments

October 4, 1985
New York City
B. P. Flannery

LAMONT-DOHERTY PROGRAM 1985 PROGRESS REPORT

SEASONAL STUDY OF THE CO2 AND TRACER DISTRIBUTIONS IN THE HIGH LATITUDE ATLANTIC, W. Broecker and T. Takahashi

- Goal: gain better understanding of the air-sea exchange of CO2 in high latitude surface waters

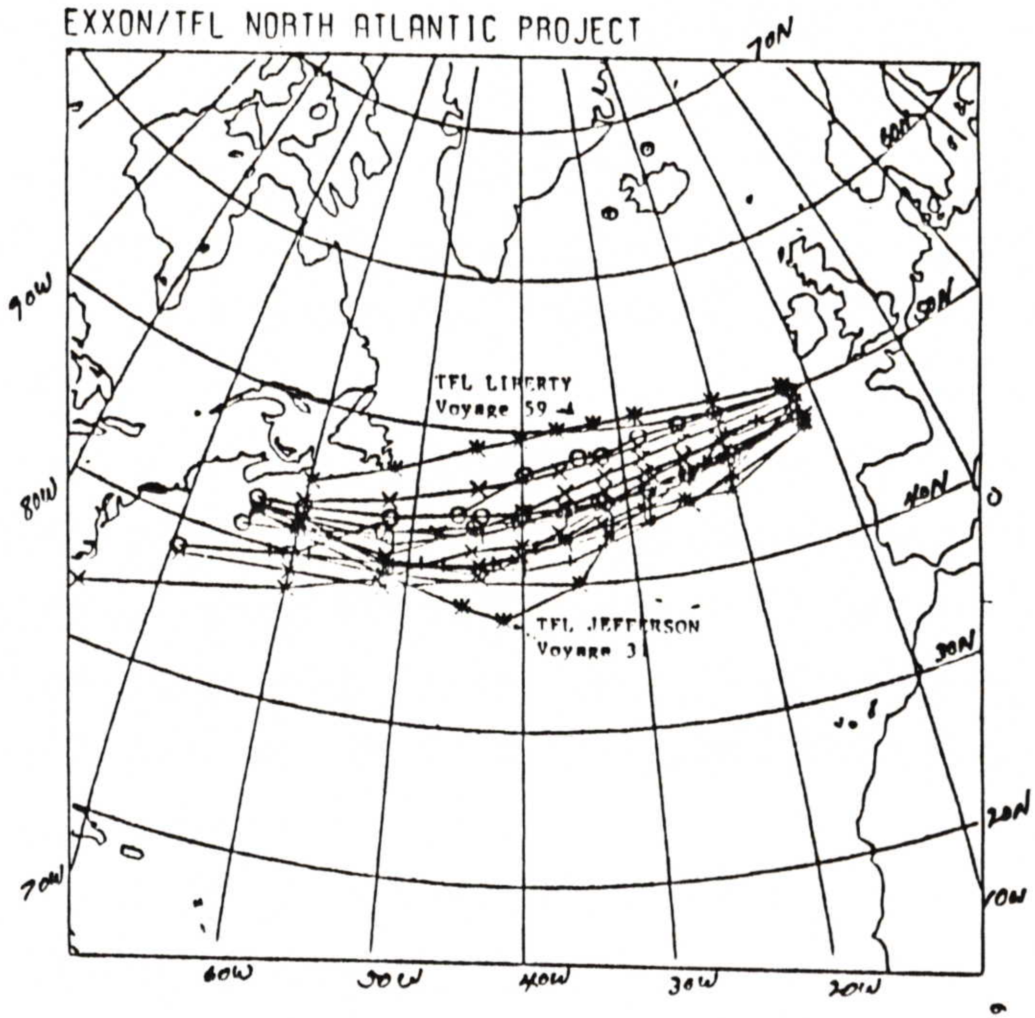
- First systematic study of seasonal CO2 chemistry in North Atlantic

- Field studies complete March 1985

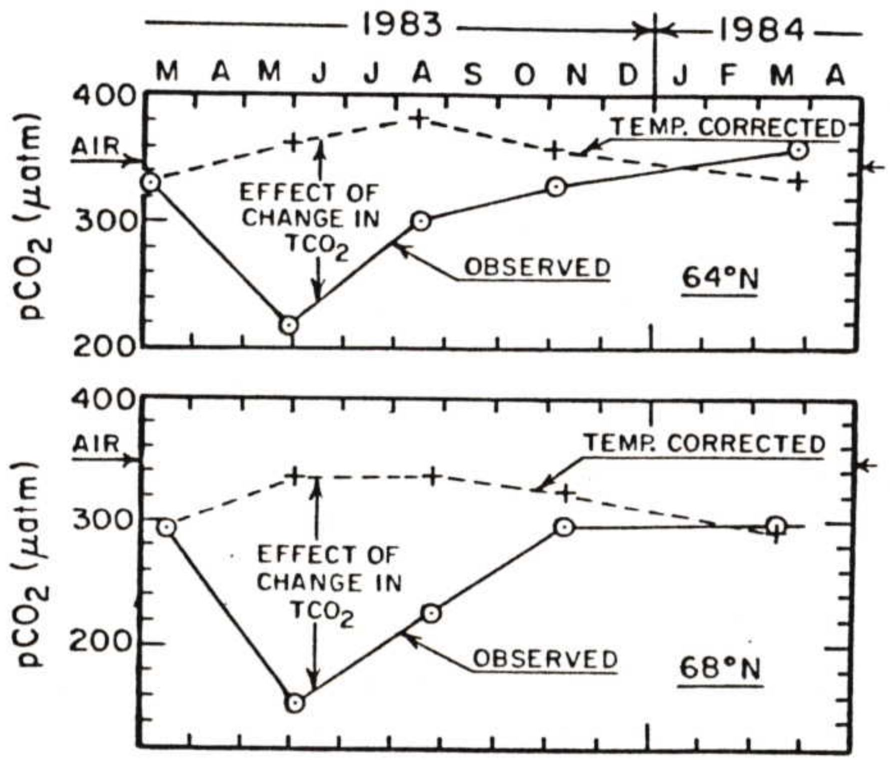
- Related studies
  + North Pacific (DOE support)
  + South Pacific (EXXON, DOE)

SAMPLING POSITIONS IN THE NORTH ATLANTIC

- Transport Freight Limited ships, Greenland stations



LARGE SEASONAL VARIATION IN P(CO2)



- Previously only summer data available, low values assumed to persist all year

PRINCIPAL FINDINGS, CONCLUSIONS

- Large, unexpected seasonal variation in P(CO_2) in high latitude surface waters

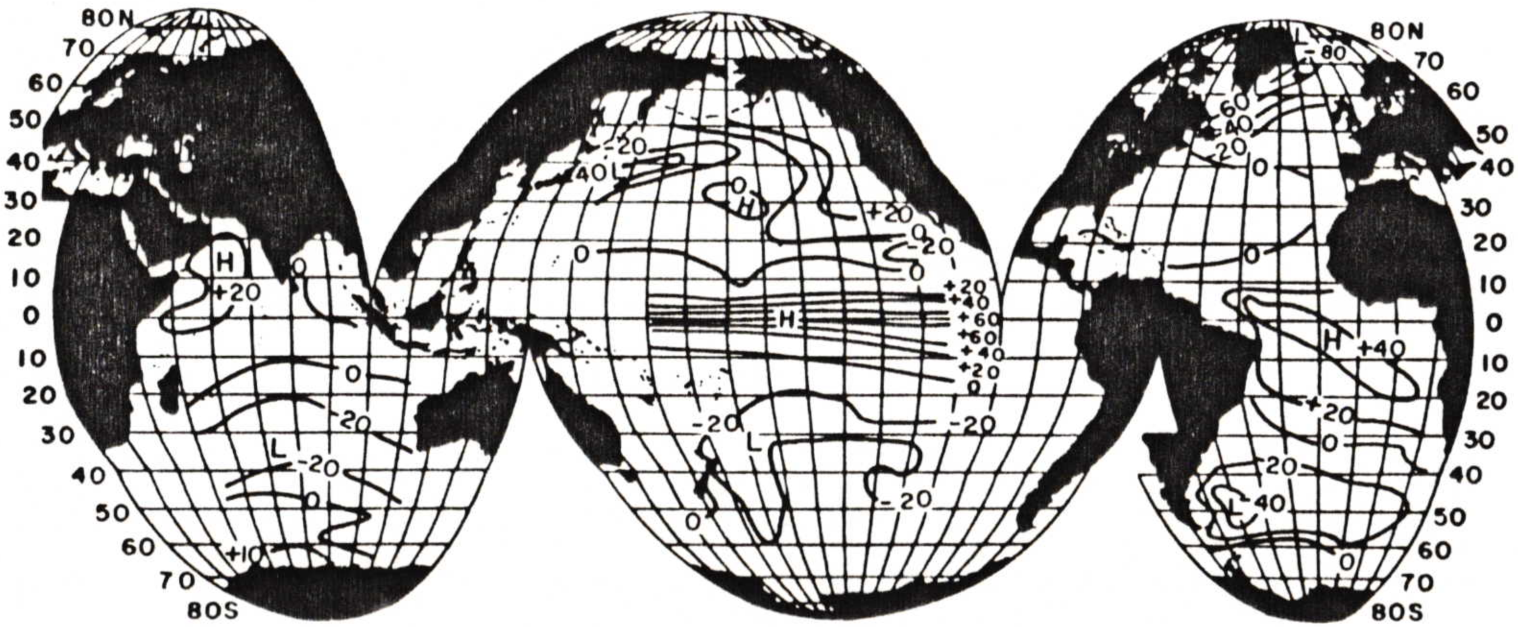
- Standard thermodynamic models for CO_2 variation cannot explain observations
  + Biology and mixing required

- Implication for CO_2 uptake by ocean two sided
  + Lower exchange from air to surface ocean
  + Higher exchange from surface to deep water

- Results need to be assessed in quantitative models of oceanic carbon cycle

AVAILABLE COMPILATION OF OCEANIC P(CO2)

- GEOSECS data (Atlantic 72, Pacific 73, Indian 78)



- No information on seasonal variation

- Much additional data acquired, but not compiled

LAMONT PROPOSAL 1986: SEASONAL AND GEOGRAPHICAL MAP OF P(CO2) IN SURFACE WATERS

- Compilation of seasonal P(CO2) map
  + All available data
  + 10 x 10 degree grid
  + February, August

- Objectives
  + Differentiate regional behavior, important effects
  + Develop a seasonal model to explain variation
  + Re-examine oceanic carbon cycle

DOE STATE-OF-THE-ART REPORT

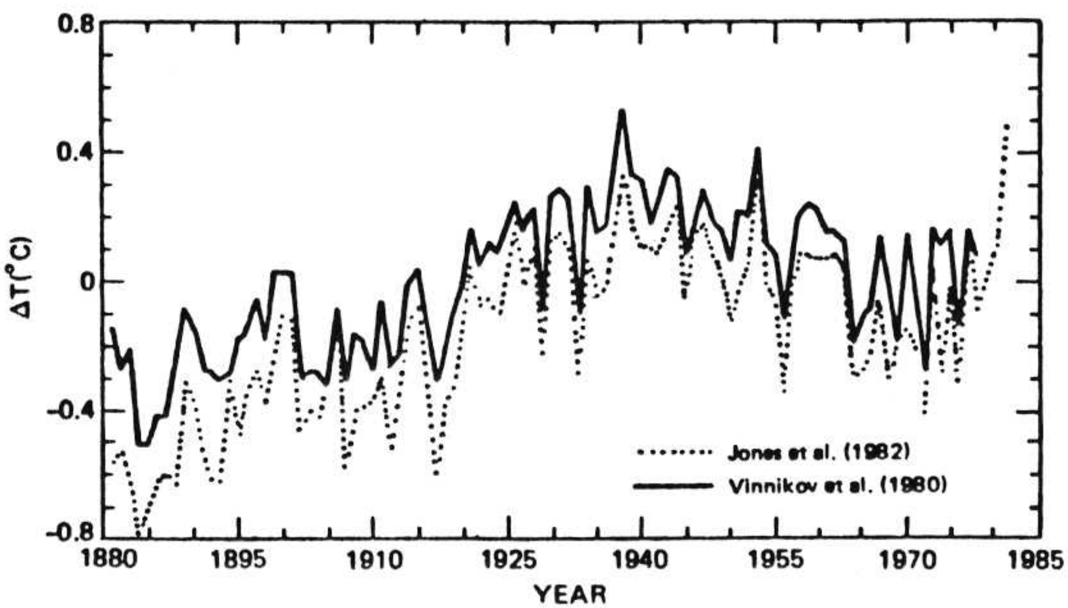
MODEL PROJECTIONS OF TIME DEPENDENT RESPONSE TO INCREASING CARBON DIOXIDE

M.I. HOFFRERT (NYU) and B.P. FLANNERY

- Observational data for modern climate (1850-1980)
- Elements of transient climate models
- Disagreement among results for steady state models
- Hindcasting for model verification
- Forecasting of future change, first effects
- Conclusions and Recommendations

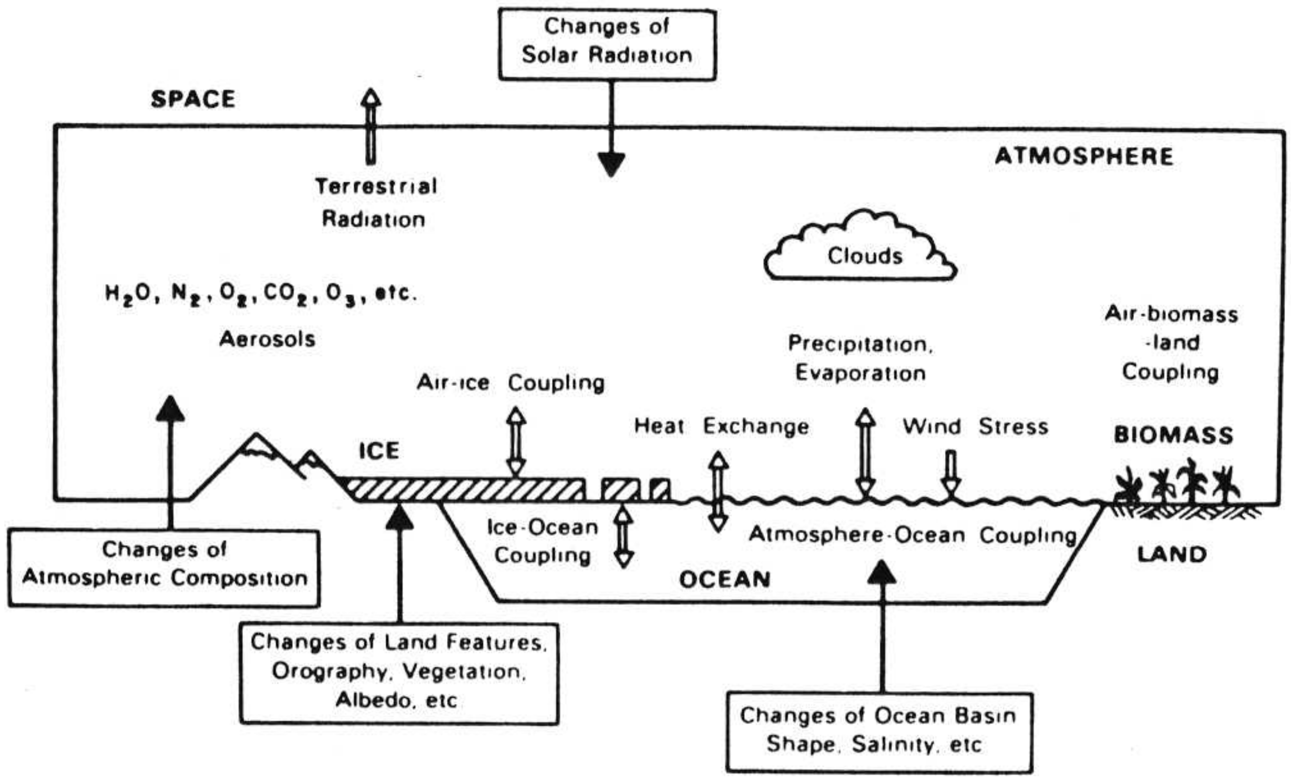
HISTORICAL DATA FOR TRANSIENT MODEL VERIFICATION

VARIATION OF GLOBAL MEAN TEMPERATURE 1880-1980



- Temperature change +0.5 C (1980-1880)
- Factors besides CO2 must operate
  + volcanoes, solar variability, oceanic upwelling
- Other archived data exist, Sea Ice, Regional Temperature, ...
  + Less reliably predicted by models
  + Display more variability, as measured

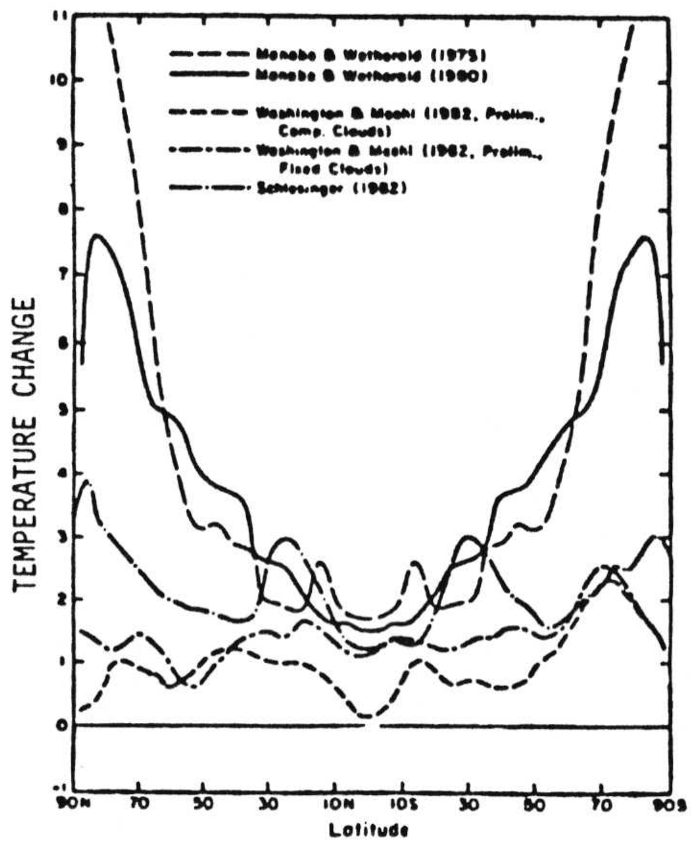
ELEMENTS OF STEADY STATE AND TRANSIENT MODELS



- Steady State response CO2 addition
  - + IR decreases, temperature rises
  - + Additional feedbacks
    - Atmospheric water vapor
    - Snow/ice cover
    - Cloudiness amounts, types
- Transient evolution, timescales
  - +Land, 1 week
  - +Atmosphere, 1 month
  - +Ocean mixed layer, 8 yrs
  - +Deep ocean,(1-10) thousand yrs

GENERAL CIRCULATION MODELS DISAGREE ON STEADY STATE RESPONSE 2xCO2

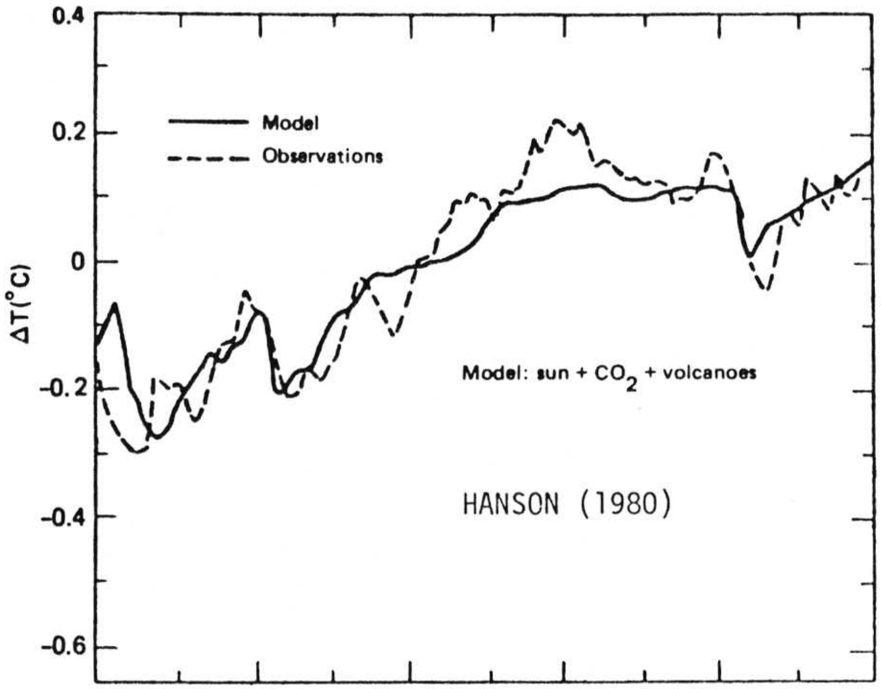
DOUBLED CO2

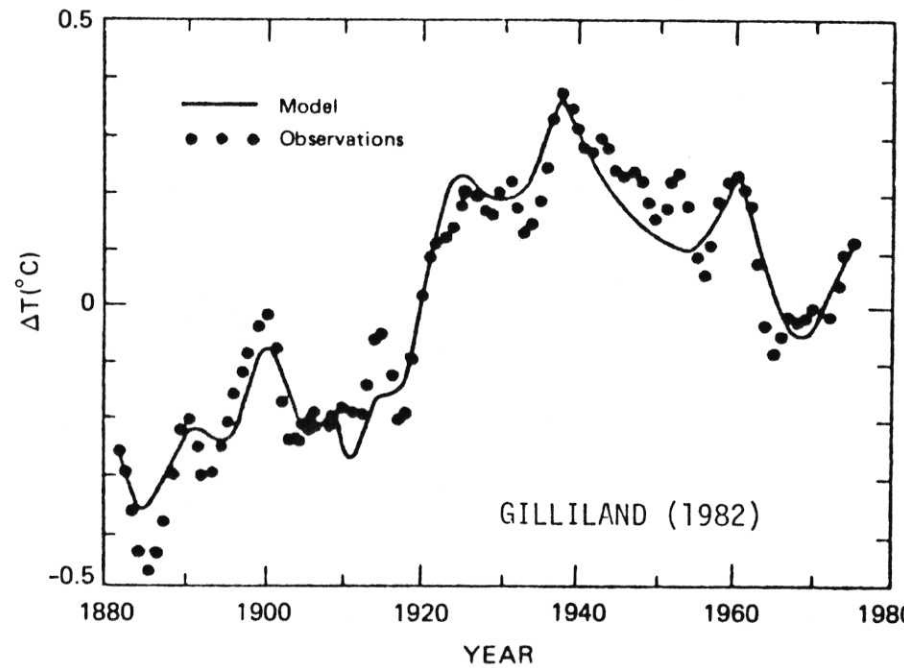


- Basic results
  - + Global mean temperature rise 1.5-4.5 C
  - + Warming greater at poles
- Major disagreement between models
- Sources of disagreement
  - + Treatment of oceanic transport
  - + Treatment of cloudiness feedback

- Recent models show 4-5 C Global warming
  - + Include other trace gasses

HINDCASTING RESULTS/ VERIFICATION





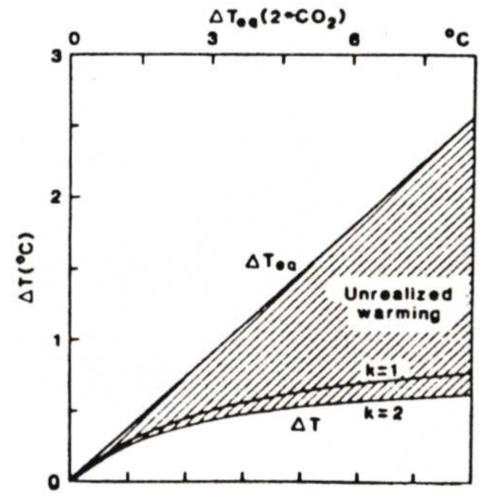
- Models claim to detect CO2 effect, but required other types of forcing
    + volcanoes, solar variation, (oceanic upwelling)

- Spurious agreement in conclusions
    + Treatment of forcing differs
    + Observational data differs

- Consensus view CO2 warming not yet confirmed by observation

FORECASTING RESULTS/ PREDICTION AND FIRST EFFECTS

- Requires forecast of future CO2 emissions



- Ocean delays CO2 warming
  + As yet unrealized warming could be substantial

- Results from General Circulation Model still unavailable
  + Inclusion oceanic transport challenging task

CONCLUSIONS/RECOMMENDATIONS

- Modern climate is forced by factors other than CO2
- Oceanic response delays warming by at least 10 years
- Consensus prediction 1 C warming (1860-2000), 2-5 C (2100)
- To date models do not provide unique forecasts
- Model development:
  + GCM results display substantial discrepancies
  + Research requires a hierarchy of climate models
  + Reliable GCM results are at least 10 years away
- Must develop improved understanding of oceanic transport
- Must develop observationally based strategies for model verification

CR RESEARCH 1984-85

- Continuing role in the environmental impact assessment of the Natuna Gas Project
- Preparation of the "Transient Climate Models" chapter of the DOE State of the Art Report on CO2 Research
- Role of oceanic effects on climate change
  + Collaborative development of a sophisticated Energy Balance Climate model (Livermore, NYU)
  + Studies of thermal lag from oceanic effects

EMERGING DILEMMA FOR CLIMATE MODELS: WHY HASN'T WARMING BEEN OBSERVED?

- Recent GCM models predict greater sensitivity

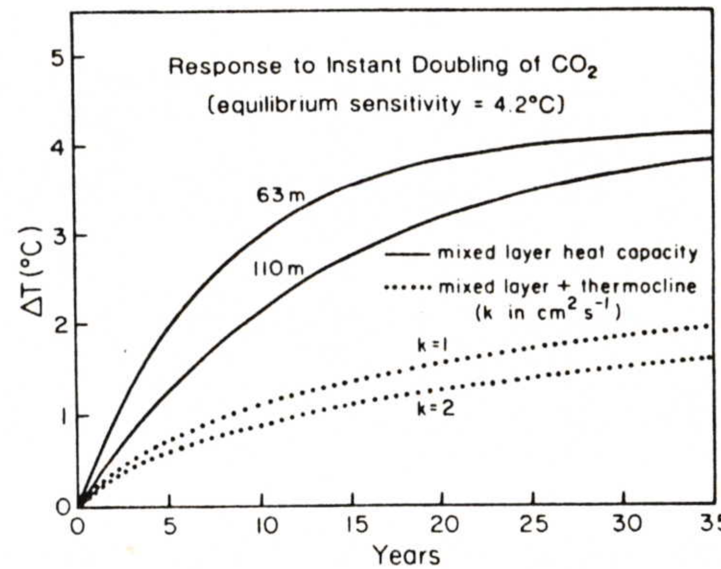
warming $2xCO_2$	(1850-1980)	
2-3 C	0.8 C	marginally detectable
4-5 C	1.6 C	readily detectable

- Proposed solution, delay from oceanic thermal buffering much greater than found in previous studies

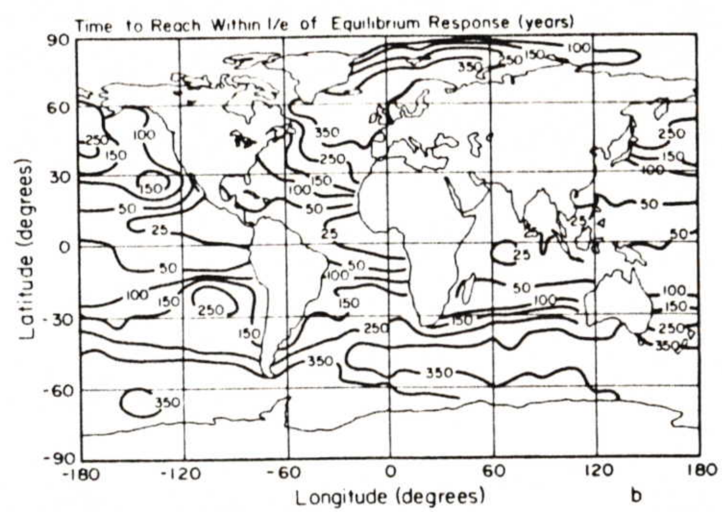
- Requires strong thermal coupling between surface and deep ocean

MODELS INCLUDING ENERGY TRANSFER TO DEEP OCEAN PREDICT LONG DELAYS FOR ATMOSPHERIC WARMING

- Purely Diffusive (PD) Model (Hansen 1984)

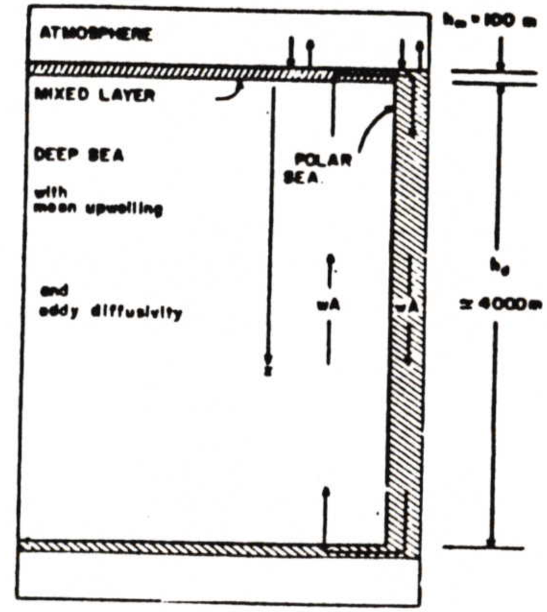


- Pattern of global response
  - + Average lag time 125 years



THE UPWELLING DIFFUSION MODEL FOR HEAT TRANSFER INTO THE MIXED LAYER AND DEEP OCEAN

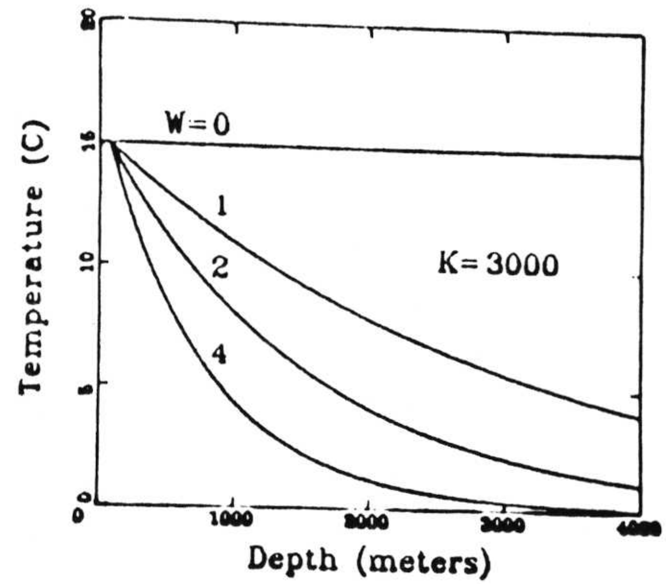
- Schematic of model (Hoffert, Callegari, Hseih 1980)



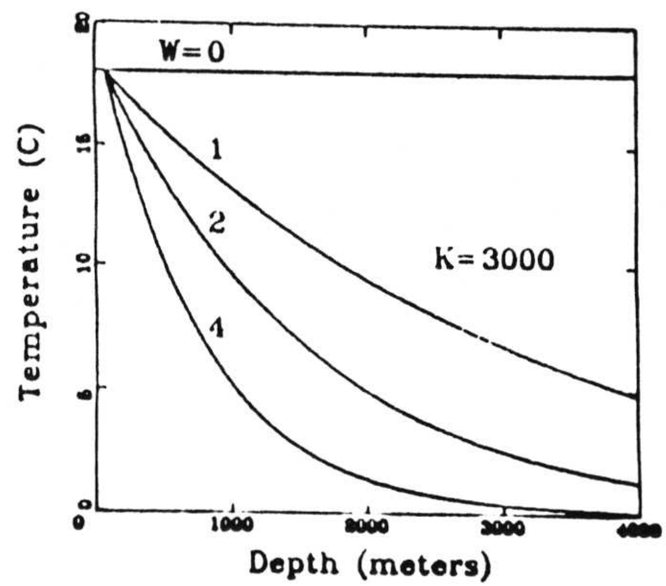
- Timescales
  - + Mixed layer heat exchange, 10 years (heat capacity)
  - + Diffussion time 5000 years
  - + Upwelling time 1000 years

COMPARISON OF STEADY STATE SOLUTIONS UPWELLING DIFFUSION (UD) AND PURELY DIFFUSIVE (PD) MODELS

- Current climate, average surface temperature 15 C

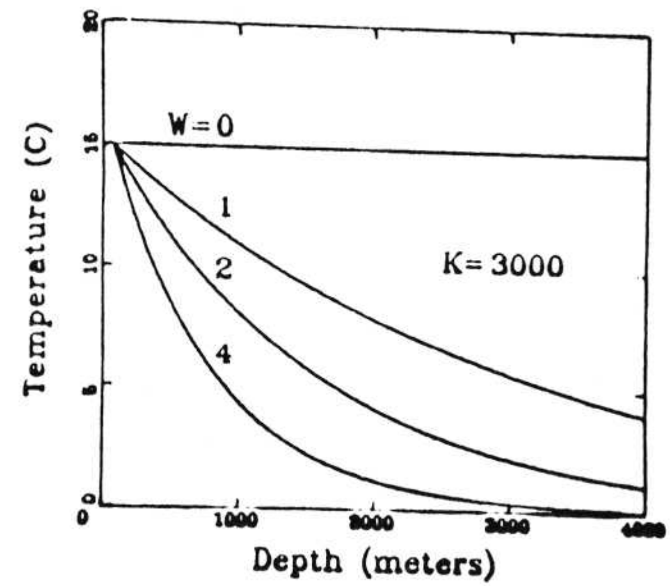


- Models with 3 C surface warming

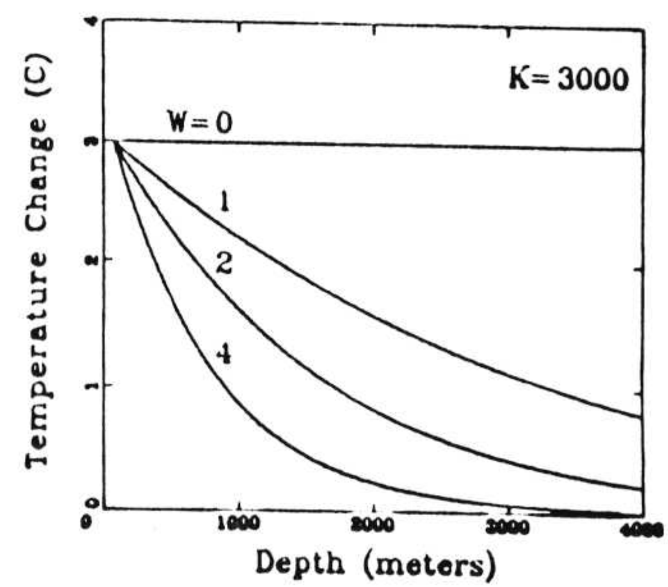


COMPARISON OF STEADY STATE SOLUTIONS UPWELLING DIFFUSION (UD) AND PURELY DIFFUSIVE (PD) MODELS

- Current climate, average surface temperature 15 C

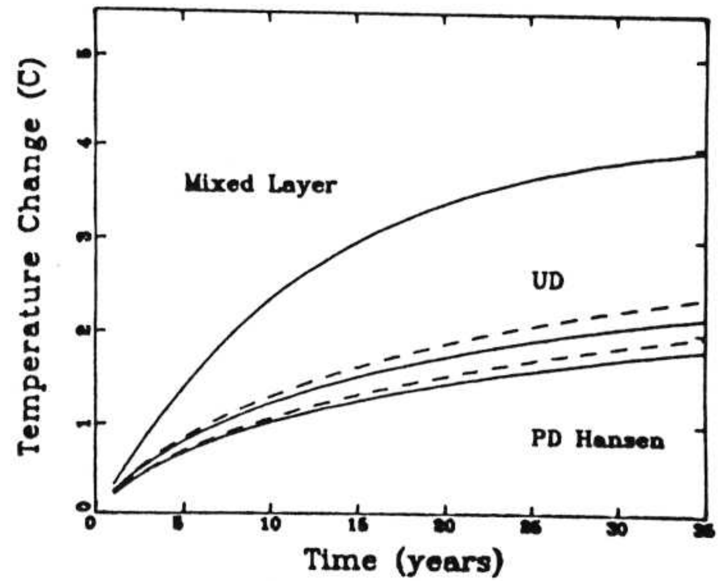


- Temperature change vs depth for 3 C surface warming
  - + PD models require maximum heating

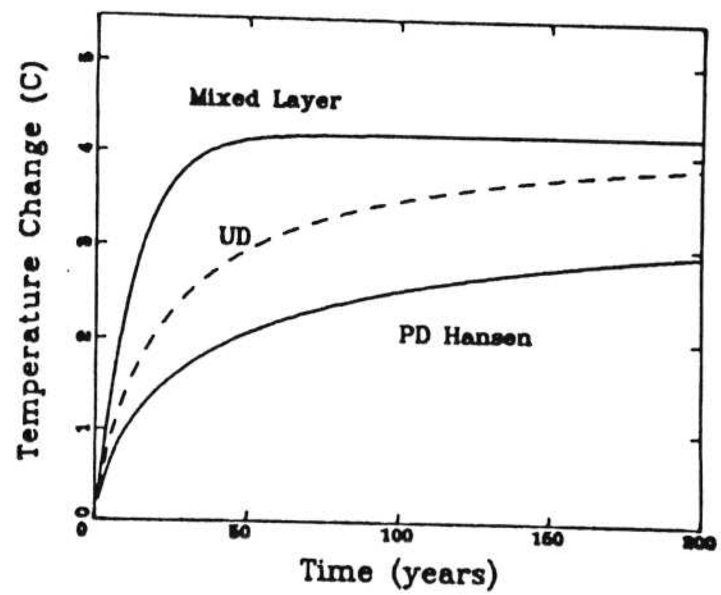


TRANSIENT EVOLUTION, COMPARISON WITH HANSEN

- Addition of upwelling decreases response time



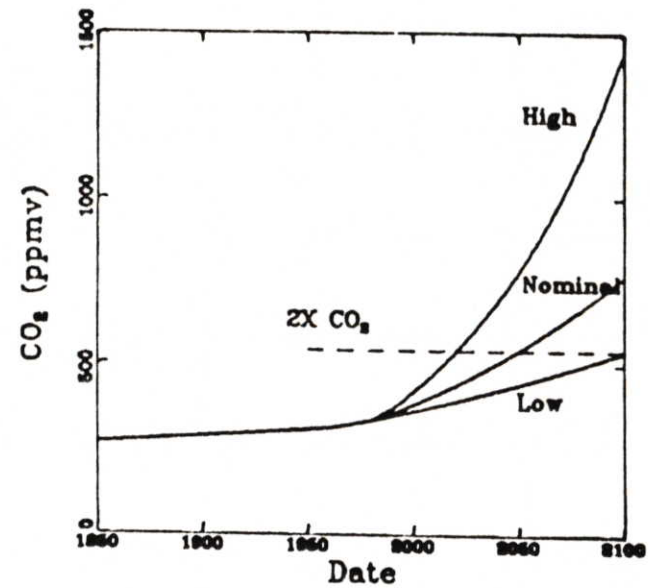
- Recalibrate Diffusion coefficient using UD model



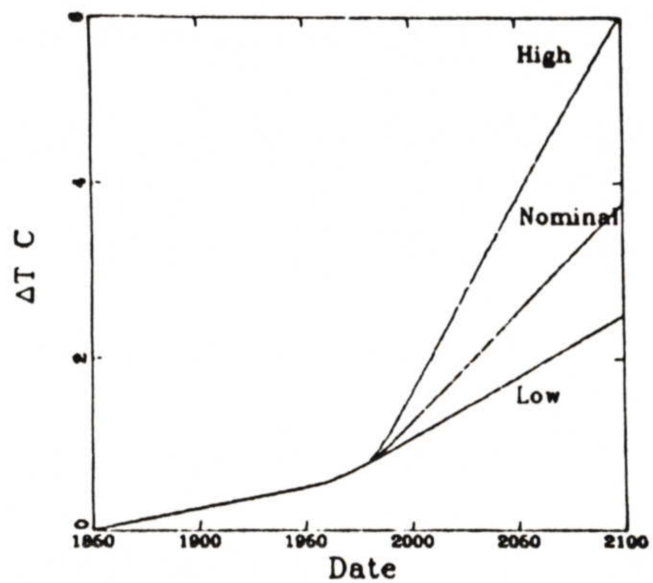
- Lag time decades

HISTORICAL AND FORECAST CO2 INCREASE 1850-2100

- CO2 record and forecasts from Weubbles (SOA Report)

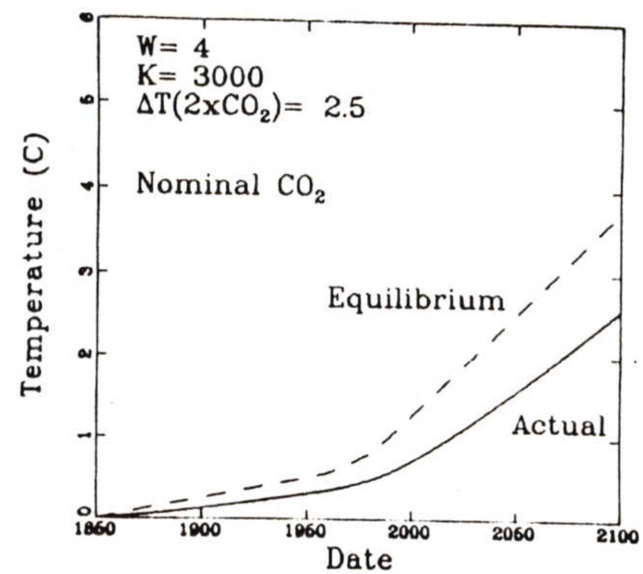


- Corresponding change in equilibrium temperature
  $+\Delta T = \Delta T(2xCO2) x \ln(CO2\ ppm/540\ ppm)$

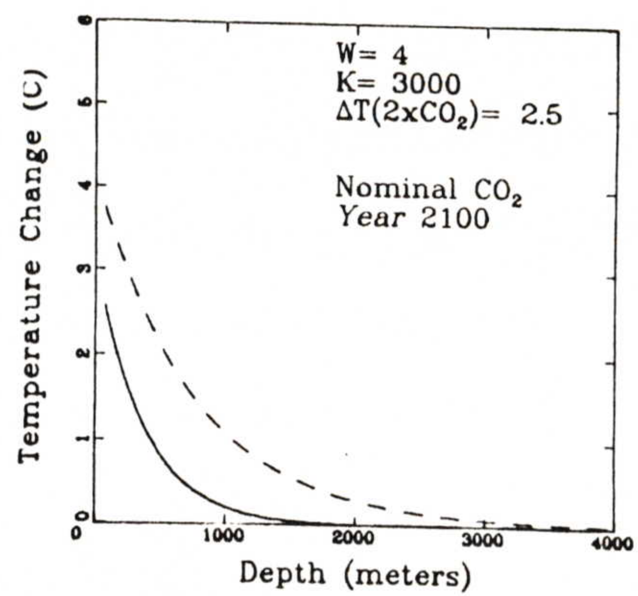


TEMPERATURE CHANGE WITH UD MODEL

- Surface temperature variation
  - + Lag time 30 years in 1983 but increases with time (poorly defined concept)

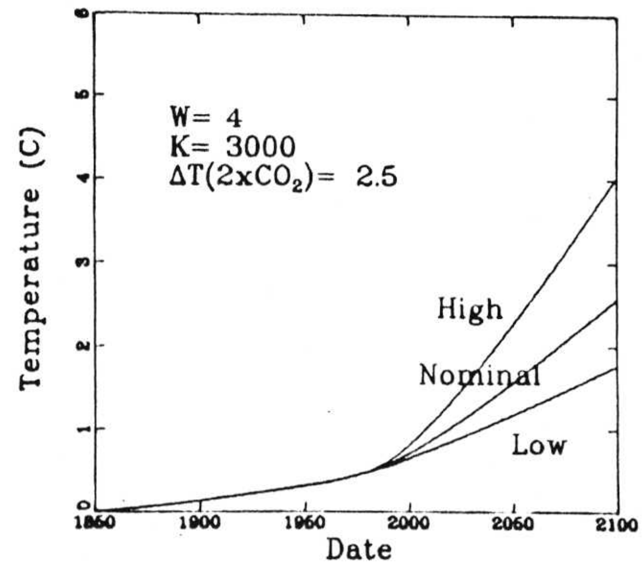


- Profile of ocean warming (year 2100)



TEMPERATURE CHANGE FOR VARIOUS CO2 FORECASTS

- Surface temperature variation
  + (1850-1985) 0.52 C
  + 1 C warming (2007, 2018, 2033)



- Lag time decades, not hundreds of years

CONCLUSIONS FROM 1D OCEAN MODEL

- Purely diffusive models overestimate response time
    - + Improper steady state solution
    - + Overestimate diffusion coefficient

- Lag time poorly defined concept to express delay in warming caused by oceans

- Response delayed by decades, 30 years, not centuries

- Simple models can contribute to understanding of oceanic effects

CR PROGRAM 1986

- Present results Transient Climate models
  - + Ocean modelling conference Woods Hole late 1985
  - + Manuscript in preparation

- Continuing development of Coupled atmosphere ocean EBM

- Monitor research and reports (SOA)

CO2 GREENHOUSE BUDGET, PROPOSAL

CR EFFORT	Projected 1985 K$	Proposed 1986 K$
Professional time	132	140
Consultants/Purchased Research	14	35
Travel	7	10
Other	4	5
Total CR	157	190
Lamont-Doherty	93	60
Total	250	250